

## HUMAN CHOICE IN "COUNTERINTUITIVE" SITUATIONS: FIXED- VERSUS PROGRESSIVE-RATIO SCHEDULES

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College undergraduates were given repeated opportunities to choose between a fixed-ratio and a progressive-ratio schedule of reinforcement. Completions of a progressive-ratio schedule produced points (exchangeable for money) and incremented that response requirement by 20 responses with each consecutive choice. In the reset condition, completion of a fixed ratio produced the same number of points and also reset the progressive ratio back to its initial value. In the no-reset condition, the progressive ratio continued to increase by increments of 20 throughout the session with each successive selection of this schedule, irrespective of fixed-ratio choices. Subjects' schedule choices were sensitive to parametric manipulations of the size of the fixed-ratio schedule and were consistent with predictions made on the basis of minimizing the number of responses emitted per point earned, which is a principle of most optimality theories. Also, the present results suggest that if data from human performances are to be compared with results for other species, humans should be exposed to schedules of reinforcement for long periods of time, as is commonly done with nonhuman subjects.

*Key words:* choice, fixed-ratio schedule, progressive-ratio schedule, optimization, verbal reports, panel press, adult humans

Different species often produce very different behavioral patterns on schedules of reinforcement. Thus, although studying these differences (as well as similarities) is a valuable enterprise, one must be extremely careful in making comparisons. This is especially true with human subjects. Of course, humans typically have substantial histories of reinforcement before entering the laboratory (Perone, Galizio, & Baron, 1988; Wanchisen, Tatham, & Mooney, 1989; Weiner, 1983); this complicates the possibilities for clear comparisons.

Some potential sources of difference are accessible to experimenters, however. For example, Perone et al. noted that procedural differences are a likely source of variability across species. Indeed, equipment for behavior-analytic work with humans has not been standardized, and methodology often varies widely among laboratories (for a discussion, with commentary, see Baron, Perone, & Galizio, 1991).

In recent years, several cross-species comparisons have been based on a procedure that entails repeated choices between a fixed-ratio (FR) schedule, which requires a fixed number of responses per reinforcement, and a progressive-ratio (PR) schedule, which increments by a certain amount with each ratio completion, thus requiring more and more responses each time it is selected. The procedures are variants of the one introduced by Hodos and Trumbule (1967) using chimpanzees and later modified slightly by Himeline and Sodetz (1987), who used monkeys. In the latter experiment, the PR increased by increments of 20 and had an initial value of 0, with an initial response required for selecting the schedule. Thus, when the PR was at its initial value of 0, the response requirement was  $1 + 0$  (or 1), the next value was  $1 + 20$ , then  $1 + 40$ , and so on. The FR value was constant within blocks of sessions, and varied across blocks. Thus, for example, with an FR value of 80, the response

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requirement was  $1 + 80$  throughout the session, including the selection requirement (or initial link) of one response. The FR values were varied over blocks of sessions from 20 to 640 in an ascending and descending geometric series. A red light corresponded with the FR, and a yellow one corresponded with the PR (whenever its response requirement was equal to its initial value of 0, the yellow light flashed once per second). In the reset condition, every completion of the FR yielded access to food and reset the PR to its initial value. In contrast, in the no-reset condition, the PR continued to increment throughout the session. In the reset procedure, the monkeys switched from the PR to the FR well before the FR equaled the PR response requirement (the "equality point"). In the no-reset procedure, they switched *at* the equality point. Both patterns constituted optimal performance, in that the numbers of responses per reinforcer were minimized on the respective procedures. These results fit the predictions of optimality theory even more closely than did the results that Hodos and Trumbule (1967) had obtained with chimpanzees. (Throughout this paper, optimality will be defined as minimizing responses per reinforcer.)

Using pigeons, Mazur and Vaughan (1987) subsequently reanalyzed Himeline and Sodetz's (1987) experiment in terms of a delayed reinforcement model that assumed a sensitivity to aggregates of four reinforcers, with sums of reciprocals of delay from point of choice to each of these reinforcers being the operative averaging principle. This analysis was predicated on assuming a constant response rate of one response per second in order to accommodate Himeline and Sodetz's response-based procedure to their time-based account. Mazur and Vaughan showed that predicted switch points were similar, whether one employed an optimality or a delayed reinforcement analysis. They also designed a procedure similar to that of Himeline and Sodetz, but included various intertrial intervals (ITIs) in a manner that changed the switch points predicted by their delayed reinforcement formula (hereafter referred to as the sum of reciprocals), while holding constant the predictions of optimality theory. Mazur and Vaughan's results were best described by their time-based formulation, and they concluded that the sums-of-reciprocals model is superior to optimality theory as a predictor of choice between schedules of reinforcement.

Also with pigeons, Wanchisen, Tatham, and Himeline (1988) used a procedure similar to that of Himeline and Sodetz (1987), again using reset and no-reset procedures. They found that, on the whole, birds in the reset condition tended to switch at points predicted by the sums-of-reciprocals formula, and to switch according to both optimal and delayed predictions when those predictions were equal (at lower FR values). Wanchisen *et al.* also reexamined Hodos and Trumbule's (1967) chimpanzee data and found that these subjects tended to switch at points above optimality and below delayed reinforcement predictions. It seems, then, that neither account fully describes the entire collection of data obtained with a variety of species in several laboratories.

Quantification of results has been a primary focus of these choice procedures (see also Fantino & Abarca, 1985; McDiarmid & Rilling, 1965), and we hoped to discover additional evidence on this topic using human subjects. The two experiments presented here systematically replicated the procedures in the Wanchisen *et al.* (1988) study.

## EXPERIMENT 1

### METHOD

#### *Subjects*

Three human adults, 2 male (S1 and S2) and 1 female (S3), were recruited from Temple University's student population through advertisements posted in the academic and administrative buildings on campus. Psychology majors and students who had taken more than one psychology course were disqualified. The subjects signed a combined commitment and consent form stipulating that they participate in at least three 1-hr sessions per week for approximately 64 hr total. Subjects were told they would earn an average of approximately \$5.00 per hour, depending upon performance, but that \$2.00 per hour would be paid for simply attending the session; this "attendance" pay would be retained by the experimenters until the experiment was completed. This feature was arranged to increase the likelihood of subjects' completing the experiment. Subjects were also told that they would be given the monetary value of the points they had earned during each experimental hour (approximately \$3.00) at the conclusion of each hour.

### *Apparatus*

A BRS Foringer intelligence panel (containing lights, counters, a Sonalert® and blank panels), which rested on a small table in the experimental room, was controlled by a PDP 8/E® computer housed in a separate room. The panel measured 53 cm wide, 58 cm high, and 71 cm deep. There were left and right push-panels, each of which was 7.6 cm high and 6.4 cm wide, positioned 16 cm apart, each 22 cm from the bottom. Above each push-panel was a panel (3.8 cm<sup>2</sup>) that could be transilluminated red or yellow. Two counters were centered 45 cm from the bottom, but only the lower one was used. Reinforcers (points worth cents) were delivered by incrementing the counter and simultaneously operating a piezoelectric speaker and a small lamp (located under the counter) for 200 ms. The experimental room measured approximately 3.7 by 1.8 m, and contained two additional desks, several stacks of paper, and empty bookshelves. A door connected this room to the experimenter's room.

### *Instructions*

Upon entering the experimental room, each subject was given an instruction sheet that stated the following:

You have just earned \$2.00 for participating in the experiment. . . in order to earn more money, that is, money over and above the \$2.00, you must now respond in such a way as to get the above counter to add. Every time the counter adds one (1) digit, you will have earned one cent. The counter will keep a running total of money you are earning for responding on the panel in front of you. Periodically, the panels will become dark. At that time, you will have 2 minutes to fill out a "guess sheet" and place it in the Guess Sheet Box.

Please do not discuss this experiment with anyone until we debrief you on the procedure in the future. You may not ask the experimenters any questions about the procedures involved in the experiment, neither during nor after each session.

Thank you for your participation.

### *Preliminary Training*

Subjects were then exposed to a variable-ratio (VR) 3 schedule for two 40-reinforcer sessions, separated by a 2-min break. Subjects were exposed to VR 20 upon returning for their second hour of experimentation. At the beginning of each session and following each

reinforcer, a white light was presented above the left or right panel, alternating pseudorandomly, and only presses on the panel beneath the illuminated lamp produced points. Within the hour, after every 40 ratios were completed, the panels darkened for 2 min and the subject filled out a "guess sheet" and deposited it into a box with a slot in front; subjects typically completed three to 10 guess sheets per experimental hour. (The procedure for the completion of the guess sheets was the same in the experiment proper.)

The following guess sheet was used throughout the experiment even though Statements 3 and 4 did not apply during training, when only a white light was used:

#### GUESS SHEET

1. The way I earn points is to . . .
2. The best way to earn points in this experiment is to . . .
3. The yellow light indicates . . .
4. The red light indicates . . .

Approximately one quarter of the page was left blank for a response to each question. These statements were designed to provide flexibility in the subjects' responses and not lead them to alter their lever-pressing pattern.

### *Procedure*

Subjects were then exposed to a series of "experimental hours," each of which contained one or more "sessions" (note that these terms are not interchangeable). Each session terminated after 40 "trials." Each trial consisted of choosing between an FR, the value of which was held constant in each condition (at least one experimental hour), and a PR, which started with a requirement of zero responses and increased by 20 additional responses each time it was selected. Each trial began with illumination of a yellow lamp (correlated with the PR) on one side and, simultaneously, a red lamp (corresponding to the FR) on the other side; schedules (colors) were pseudorandomly assigned to each panel with equal probability at the start of each trial. When the PR was equal to zero the yellow light repeatedly flashed on and off, with the off-and-on periods equal to 0.5 s. The first responses on either panel resulted in its lamp remaining on until the corresponding schedule requirement was satisfied, and darkening of the nonselected schedule's panel. Responses on the unlit side had no programmed conse-

quences. The choice response was not counted toward satisfying schedule requirements. Hence, selecting the PR required one response (one indicating choice and zero for the initial PR) to produce its first reinforcer of the session, then  $1 + 20 = 21$ , then  $1 + 40 = 41$ , and so forth. The FR was also preceded by a choice response of one so, given an FR 60, the total response requirement was  $1 + 60$ , or 61, every time it was selected. Completing the response requirement on the illuminated side turned off the stimulus lamp and produced two points, redeemable for 2 cents. The reinforcer counter kept a running total of earnings over the course of the experimental hour. Importantly, in this experiment, every selection (and completion) of the FR reset the PR to its original value of zero.

The values of the FR, which were varied over blocks of 40-reinforcer sessions, were 20, 60, and 120, with a given FR remaining remaining in effect for a minimum of 12 and a maximum of 24 sessions (and possibly more if criterion was met at midhour), depending upon when responding stabilized. All subjects started the series at FR 60, but each subject received a different series. Designating the FR values as A = 60, B = 20, C = 120, Subjects 1, 2, and 3 received A-B-A-C-A, A-C-A-B-A, and A-B-C-A, respectively.

Following each 40-trial session was a 2-min intersession interval, in which the panel darkened and was inoperative, and the subject filled in a guess sheet that was deposited in the box. If a subject was in the middle of a session when the experimental hour concluded, the apparatus would shut down midsession and the subject was paid for the trials completed; however, data obtained from partial sessions were eliminated from analysis.

*Stability criteria.* The FR value for a given subject was changed when stability criteria were met (these were the same criteria we had imposed on pigeons in Wanchisen *et al.*, 1988). Subjects typically began sessions by selecting the PR on successive trials up to a particular point at which they usually switched to selecting the FR, thus resetting the PR to its minimal value. The value of the PR at which the subject chose the FR at that PR (and all higher PR values) with a probability of at least .80 was designated as the "probabilistic switch point." Restated, this measure corresponded to the *lowest* PR value at which the subject

chose the FR at least 80% of the trials. (PR values at which the subject had fewer than 10 opportunities to choose the FR were excluded from determination of probabilistic switch points.) By convention, PR selections were specified in terms of the values confronting the subject at the beginning of the trial. Hence, for example, "switching at PR 80" means "switching to the FR when faced with a PR requiring 80 responses," and that the last PR value *completed* was 60. Data were pooled across blocks of three sessions.

The first three-session block of data from every new condition was considered transitional and was not used to determine stability. When the probabilistically determined switch point remained the same for two consecutive three-session blocks, subjects received a final three-session block prior to contingency changes. Also, meeting these criteria during an experimental hour did not alter the experimental contingencies during that hour; that is, we did not interrupt the subject to change the condition. Any "extra" data obtained this way were not included in the analysis. Condition changes were always instituted at the beginning of the experimental hour. Therefore, a subject could remain on one condition for a minimum of four blocks (or 12 sessions; i.e., the first block as transition, two blocks of switching at the same value, and the final block). Whenever a subject did not meet the criterion within 21 sessions, he or she was exposed to three additional sessions, for a total of 24 sessions, and was then moved to the next FR value.

## RESULTS

*Median switch points.* Figure 1 shows median switch points, for every session, in the order of FR presentation. The median switch point was the PR value above and below which there were equal numbers of FR choices. (The probabilistic switch points, although used to determine stability, are not presented here primarily because subjects did not always meet the stability criterion and were moved to the next condition based on number of sessions completed.) The solid horizontal line depicts the optimal switch point for each condition. The vertical lines indicate the fourth spread (F spread), a measure of variability appropriate to medians, which is calculated by dividing a distribution in half at its median and

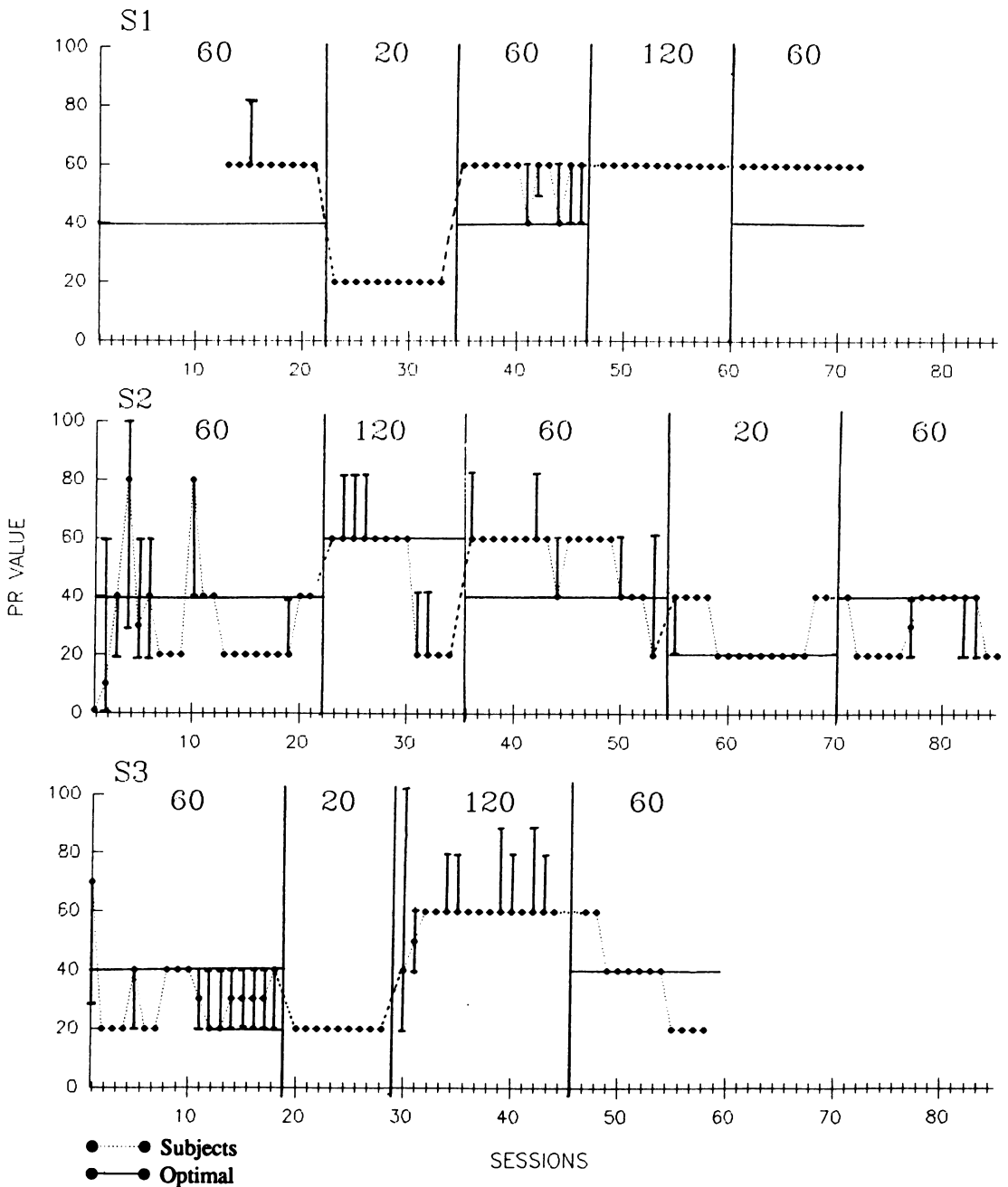


Fig. 1. Session-by-session median switch points for each reset condition, for every subject, in the order of FR presentation. The solid horizontal lines indicate, for the FR value, switch points corresponding to minimal numbers of responses per reinforcement. The solid vertical lines indicate the F spread, a measure of variability about the median.

then calculating the medians of the two resultant distributions. The distribution below the median is referred to as the "lower fourth" and the distribution above as the "upper fourth." The vertical lines, then, connect the

medians to fourths to produce the spread of a subject's choices. This statistic is analogous to the perhaps more familiar interquartile range that is appropriate when showing the variability about means, but is preferable to in-

Table 1

The condition median and final-block median for each subject in the reset condition. Optimal switch point at a given FR is provided on the right for comparison.

FR value	Condition medians			Final block			Optimal switch
	S1	S2	S3	S1	S2	S3	
20	20	20	20	20	20	20	20
60 (1)	60	20	20	20	20	20	40
60 (2)	60	60	—	50	40	—	40
60 (final)	60	20	40	60	20	20	40
120	60	60	60	60	20	60	60

terquartile ranges in showing variability about medians (Hoaglin, Mosteller, & Tukey, 1983). The absence of vertical lines indicates no variability in switching (i.e., the subject switched at that value throughout the session).

S1 quite reliably switched at PR 60 when the FR value was either 60 or 120, even though this constituted optimal performance only under the latter condition. On FR 20, S1's median switch point was constant at PR 20, which corresponded to optimality. The switch points for S2 and S3 fluctuated most during their initial exposure to FR 60; however, their performance became more orderly in subsequent conditions. S2's pattern of switching is particularly interesting in that he typically switched reliably at a particular PR value and then suddenly began switching at a different PR value and stayed with that value for several sessions. For example, in the FR 20 condition, he switched at PR 40 for four sessions, then at PR 20 for nine sessions, and returned to PR 40 for the final two sessions. After considerable fluctuation in the first few sessions of this subject's initial exposure to FR 60, he settled down to fairly stable switching at PR 20. His switching on FR 60 appears to have been partially controlled by preceding FR values, because upon returning from FR 120 to FR 60, he tended to switch at relatively higher values; after FR 20, there was a tendency to switch at lower values. S3 was more consistent than S2, particularly during the FR 20 and FR 120 conditions.

Examination of F spreads (shown as vertical lines through points in Figure 1) shows that S2 and S3 had greatest within-session variability in their first FR 60 condition, with some variability seen in the later FR 120 condition. In the other conditions, session-by-session variability was sporadic, if present at all. S1

may have been variable in his first FR 60 exposure, but many of the initial data were lost due to a computer malfunction. His second FR 60 condition showed substantial within-session variability by the seventh session, but, overall, this subject showed fairly reliable switching with little variability in session medians.

In short, the subjects' patterns of switching clearly were sensitive to the size of the FR alternative. When that alternative was at either extreme (i.e., either 20 or 120), switching tended to occur at the PR value corresponding to optimality (PR 20 and PR 60, respectively). At the intermediate PR value of 60, the results were less consistent, with possible carryover effects from preceding conditions.

As a summary of the switch points, Table 1 shows two values: (a) the condition median for each subject, calculated by including all of the individual switch points obtained in the condition, and (b) the final three-session block. FR values are presented in ascending order; note that the FR 60 includes a parenthetical reference to the first, second, or third (final) exposure. For comparison purposes, the optimal switch point is presented on the far right. First, considering the condition medians, subjects showed some sensitivity to the changing FR value. Consistent with the daily medians (Figure 1), all subjects had the same median switch point for the lowest (20) and the highest (120) FR value, consistent with optimality predictions. The greatest variability was seen across the three FR 60 exposures, with subjects either over- or undershooting the optimum (except in one case, S3's final exposure).

The data for the final three-session block presented on the right side of the table indicate that all subjects were performing optimally by the end of the first condition (FR 60[1]) and

that this was also true for the FR 20 condition. The other two FR 60 conditions produced greater differences between the subjects, most especially in the final FR 60 condition. Here we see 1 subject (S1) overshooting the optimum and 2 (S2 and S3) undershooting it. Finally, 2 of 3 subjects switched optimally on the FR 120, with 1 (S2) greatly undershooting that value by the end of the condition.

*Verbal report analysis.* There were nearly 2,000 total verbal report items, approximately 600 for each subject, taken from both Experiments 1 and 2. These reports were read by the authors, who subsequently defined descriptive categories into which these reports fell. A dictionary of these categories was prepared with instructions (Appendix B) for the raters who actually analyzed the reports.

There were three continuous and 34 discrete categories. The continuous categories were quantitative measures taken from the verbal reports: *word count* (WDCNT), defined as the number of words in the written response to a particular question; *red count* (REDCNT), the number of responses the subjects reported as being required on the FR; and *yellow cycle* (YELCYC), the number of reported PRs chosen before switching to the FR. A large number of discrete categories was developed so that at a later time they could be collapsed as needed. Some of the discrete categories were designed to differentiate self-descriptive statements such as "I respond quickly" (Category 1) from contingency-based descriptions such as "The reason I respond quickly is to . . ." (Category 2). Other categories differentiated statements referring to patterns or strategies of responding (Categories 18 through 22) from those indicating that either there was no pattern or that the subject could not discover what it was (Categories 9 and 23).

Problems with recognition of handwriting were avoided by typing each verbal report on a separate sheet of paper. Questions left blank were transcribed as a blank sheet. Concealed identifying information was included on each sheet (indicating subject number, date, condition, guess sheet number, etc.). For each of the four questions, the answers of the 3 subjects were shuffled together and then two photocopies of each were prepared.

Two undergraduate students, who were unfamiliar with this experiment, agreed to rate (categorize) these verbal reports and were given

several practice sessions to become familiar with the dictionary of coding terms. Independently, they read each verbal report and wrote down the categories that applied. They typically rated from 30 to 70 reports in a rating session, which rarely exceeded 1 hr in length (to avoid potential rater drift). When they were finished rating a given set of verbal reports, a third person, an arbiter, compared the categories and identified inconsistencies in their choices. The two raters then discussed, in the presence of the arbiter, why they had chosen particular categories, and either came to an agreement or the verbal report was pulled to be resubmitted to them at a later time. Whenever arbitration failed to resolve the disagreement, disputed data were excluded from subsequent analysis.

As the rating process proceeded, the rating team suggested revisions be made to the dictionary. As dictionary revisions were made, already-rated verbal reports were reanalyzed.

Table 2 displays the probability of emitting each verbal category as a function of each experimental phase (change in FR value) and is broken down by the four questions on each guess sheet. (Although all 3 subjects' verbal reports were analyzed, only S1's data are presented here.) These probabilities were computed by categorizing each guess sheet in terms of whether the subject switched at the optimal switch point during the session ("optimal session") immediately preceding administration of the questionnaire. The number of instances of each category within a phase, question number, and level of optimality (optimal vs. inoptimal) was then divided by the total number of opportunities to emit the category at that level of analysis. For example, in Phase 3 of S1's participation, there were two sessions in which switching was optimal and 10 in which switching was inoptimal. Hence, Question 1 was asked twice following optimal sessions and 10 times following inoptimal sessions. Category 32 occurred once in response to Question 1 during this phase and hence had a probability for optimal sessions of .5 (one instance divided by two optimal sessions), whereas it was emitted once following the 10 inoptimal sessions of this phase, yielding a probability of emission during inoptimal sessions of .1. By separating computing the probability of each category for optimal and inoptimal values within each phase and question number, it was

Table 2

The probability of S1 emitting a particular category of verbal response in each FR value presented. See text for full explanation.

SUBJECT: 1		QUESTION 1				QUESTION 2				QUESTION 3				QUESTION 4						
FR VALUE	CATEGORY	PROB. OPT	INOPT	OBS. OPT	INOPT	CATEGORY	PROB. OPT	INOPT	OBS. OPT	INOPT	CATEGORY	PROB. OPT	INOPT	OBS. OPT	INOPT	CATEGORY	PROB. OPT	INOPT	OBS. OPT	INOPT
FR60	14: LSSWKSES	-	.13	-	.8	02: YFAST	-	.13	-	.8	10: EXCLAM	-	.13	-	.8	10: EXCLAM	-	.13	-	.8
	17: MREWK	-	.13	-	.8	19: RED2PAT	-	.13	-	.8	17: MREWK	-	.13	-	.8	11: IBEPECTR	-	.13	-	.8
	26: MATH	-	.13	-	.8	21: LOOKPAT	-	.13	-	.8	21: LOOKPAT	-	.25	-	.8	25: YPRESS	-	.13	-	.8
	02: YFAST	-	.25	-	.8	27: MONEY	-	.13	-	.8	09: NOCLUE	-	.50	-	.8	27: MONEY	-	.13	-	.8
	27: MONEY	-	.25	-	.8	28: VARIED	-	.13	-	.8						09: NOCLUE	-	.38	-	.8
	21: LOOKPAT	-	.38	-	.8	09: NOCLUE	-	.50	-	.8						20: PATTRN	-	.38	-	.8
	28: VARIED	-	.38	-	.8															
FR20	13: FLASHY	.08	-	.12	-	33: ACCURACY	.08	-	.12	-	18: RED2Y	.08	-	.12	-	16: LSSWK	.08	-	.12	-
	22: FOUNDPAT	.08	-	.12	-	01: IFAST	.17	-	.12	-	19: RED2PAT	.08	-	.12	-	18: RED2Y	.08	-	.12	-
	33: ACCURACY	.08	-	.12	-	16: LSSWK	.17	-	.12	-	20: PATTRN	.08	-	.12	-	19: RED2PAT	.08	-	.12	-
	10: EXCLAM	.17	-	.12	-	20: PATTRN	.17	-	.12	-	08: BLANK	.75	-	.12	-	20: PATTRN	.08	-	.12	-
	25: YPRESS	.17	-	.12	-	32: ANTICIP	.17	-	.12	-						08: BLANK	.33	-	.12	-
	32: ANTICIP	.17	-	.12	-	08: BLANK	.67	-	.12	-						26: MATH	.33	-	.12	-
	34: TIME	.17	-	.12	-											06: AGGRESS	.42	-	.12	-
	27: MONEY	.25	-	.12	-											27: MONEY	.42	-	.12	-
01: IFAST	.33	-	.12	-																
20: PATTRN	.42	-	.12	-																
FR60	20: PATTRN	.50	.60	2	10	25: YPRESS	.00	.10	2	10	08: BLANK	.50	.50	2	10	06: AGGRESS	.00	.10	2	10
	14: LSSWKSES	.00	.10	2	10	26: MATH	.00	.10	2	10	01: IFAST	.00	.10	2	10	16: LSSWK	.00	.10	2	10
	24: IPRESS	.00	.10	2	10	16: LSSWK	.00	.20	2	10	16: LSSWK	.00	.10	2	10	19: RED2PAT	.00	.10	2	10
	33: ACCURACY	.00	.10	2	10	20: PATTRN	.00	.20	2	10	19: RED2PAT	.00	.10	2	10	20: PATTRN	.00	.10	2	10
	34: TIME	.00	.10	2	10	34: TIME	.00	.20	2	10	29: FIXED	.00	.10	2	10	27: MONEY	.00	.10	2	10
	08: BLANK	.00	.20	2	10	08: BLANK	1.00	.60	2	10	33: ACCURACY	.00	.10	2	10	08: BLANK	1.00	.60	2	10
	01: IFAST	.50	.20	2	10						34: TIME	.00	.10	2	10					
	32: ANTICIP	.50	.10	2	10						20: PATTRN	.00	.30	2	10					
21: LOOKPAT	.50	.00	2	10																
26: MATH	.50	.00	2	10																
16: LSSWK	1.00	.00	2	10																
FR120	26: MATH	.08	-	.12	-	20: PATTRN	.08	-	.12	-	34: TIME	.08	-	.12	-	16: LSSWK	.08	-	.12	-
	01: IFAST	.17	-	.12	-	08: BLANK	.83	-	.12	-	20: PATTRN	.17	-	.12	-	19: RED2PAT	.08	-	.12	-
	08: BLANK	.17	-	.12	-						16: LSSWK	.25	-	.12	-	11: IBEPECTR	.17	-	.12	-
	10: EXCLAM	.17	-	.12	-						08: BLANK	.58	-	.12	-	18: RED2Y	.17	-	.12	-
	17: MREWK	.17	-	.12	-											08: BLANK	.67	-	.12	-
	24: IPRESS	.17	-	.12	-															
	28: VARIED	.17	-	.12	-															
	34: TIME	.17	-	.12	-															
27: MONEY	.25	-	.12	-																
20: PATTRN	.67	-	.12	-																
FR60	06: AGGRESS	-	.08	-	.12	33: ACCURACY	-	.08	-	.12	01: IFAST	-	.08	-	.12	17: MREWK	-	.08	-	.12
	12: YBEPECTR	-	.08	-	.12	17: MREWK	-	.17	-	.12	21: LOOKPAT	-	.17	-	.12	21: LOOKPAT	-	.08	-	.12
	17: MREWK	-	.08	-	.12	02: YFAST	-	.25	-	.12	09: NOCLUE	-	.75	-	.12	20: PATTRN	-	.17	-	.12
	28: VARIED	-	.08	-	.12	21: LOOKPAT	-	.25	-	.12						09: NOCLUE	-	.75	-	.12
	34: TIME	-	.08	-	.12	09: NOCLUE	-	.67	-	.12										
	01: IFAST	-	.17	-	.12															
	11: IBEPECTR	-	.17	-	.12															
	33: ACCURACY	-	.17	-	.12															
09: NOCLUE	-	.42	-	.12																
21: LOOKPAT	-	.50	-	.12																
02: YFAST	-	.58	-	.12																

possible to assess whether some verbal responses varied with optimal schedule performance. This covariance was quantified by subtracting the probability of emitting each category following an inoptimal session (inoptimal probability) from the category's probability following optimal sessions; a positive difference indicates that the category was more likely following an optimal session, whereas a negative value is indicative of the category occurring more frequently following optimal sessions. By way of example, using the data from the preceding example, the differential likelihood of emitting Category 32 was .5 (optimal probability) - .1 (inoptimal probability). This differential probability measure can range from -1.0, indicating that the category was emitted only when switching was inoptimal, to 1.0, indicating that the category was emitted if and only if the subject switched optimally.

S1's first- or second-most frequent response to Question 1 ("The way I earn points is to...") was pattern-related across all FR values.

The specific statements made, though, appear to have varied according to whether this subject's switching within a condition was predominantly optimal or inoptimal. In phases during which responding was predominantly inoptimal (all exposures to FR 60), statements relating to looking for a pattern predominated, whereas during phases characterized by optimal switching (FR 20 and 120), pattern-oriented statements were characterized by stating that a fixed pattern of choosing was being executed rather than sought.

In essence, S1 said that he was looking for an ideal pattern when he was performing inoptimally, and that he was executing an ideal pattern when he was, in fact, performing optimally. S1's second exposure to FR 60 provided an opportunity to examine, within a single condition, whether any statements covaried with optimal switching, because this condition (unlike other conditions) contained sessions in which switching occurred at both optimal and inoptimal points. The category that most

Table 3

For S1, the mean number of reported selections of the PR (YELCYC), the value of the FR (REDCNT), and the number of words written (NWD CNT). These were based on FR value and whether or not the subject was behaving optimally (1) or inoptimally (0) on the operant task. The actual number of verbal emissions this subject made concerning selection of the yellow stimulus is indicated as NYELCYC and the actual number of reported red selections is NREDCNT.

FR value	Optimal	YELCYC	REDCNT	NWD CNT	NYELCYC	NREDCNT
60	0	2.5	60	32	4	3
20	1	1.0	10	48	6	1
60	0	2.2	50	40	5	4
	1	3.0	60	8	1	1
120	1	2.6	85	48	5	4
60	0	2.6	31	48	5	2

strongly differentiated between optimal and inoptimal sessions was 16, which was scored when the subject stated that the way he or she is responding is less work than alternative ways; this category was emitted following each of the two optimal sessions but never following any of the 10 inoptimal sessions. The tendency to refer to "looking for the pattern" following inoptimal sessions and "emitting the pattern" in conjunction with optimal sessions is also reflected in the responses to Question 2 ("The best way to earn points in this experiment is to . . ."). Consistent with his typically inoptimal performance during the first and fifth phases, both of which were FR 60, S1 indicated that he had "no clue" (Category 9) on at least half of his questions 2, 3, and 4 during these phases. In contrast, during the phases in which some or all of his choices were optimal, this category was never emitted in response to Question 2.

S1's verbal behavior appears to have been sensitive to the reset contingency, despite failures in several phases to perform optimally. Beginning in the second phase, in which the FR was 20, and continuing through the succeeding FR 60 and 120 phases, he indicated that pressing the red panel reset the contingencies and that pressing the red panel caused the yellow panel to blink or reset (Categories 18 and 19).

The data from the other subjects were not nearly as rich as those of S1 and hence are not presented in the table. S2's data consisted predominantly of answering Questions 1 and 2 by saying "I make the counter beep"; responses to Questions 3 and 4 were almost entirely of the form, "I don't know." S3 may have misunderstood Question 1 ("The way I earn points is to . . ."), because her only response to this

question was Category 11 (IBEEPCTR), typified by "I respond to get the counter to beep." Similar to S1, S3's verbal behavior reflected sensitivity to the reset contingency in that she indicated that there was a pattern to execute and that responding on the red panel would reset the yellow schedule, as reflected by emitting Categories 18, 19, and 20. Despite this verbal sensitivity to the nature of the contingencies, emission of these categories was not differentially correlated with optimal schedule performance. Indeed, analysis of the categorical data for this subject does not reveal any categories that are consistently related to the optimality of schedule selection, unlike the data of S1.

In general, this analysis failed to detect strong evidence that the verbal behavior of these subjects was strongly related to their schedule performance, although S1 showed weak evidence of a relationship between his verbal and non-verbal operant behavior.

Table 3 presents data for S1 from the continuous categories averaged across all sessions within a condition, without regard to question number. Data are presented separately for sessions in which operant switching was and was not optimal, so that differences in verbal behavior occasioned by changes in operant performance may be assessed. Data were also analyzed by questions and replication, but those analyses are not presented because they do not alter the basic pattern of results.

S1 furnished the most complete set of data of the 3 subjects. Note, though, that on FR 20 and 120 this subject always switched optimally, so it is not possible to compare relationships between verbal behavior and differential switching within these schedule conditions. S1 referred to selecting the yellow

schedule once before switching to the red schedule when the FR was 20, as shown by the YELCYC value of 1; this is consistent with his switching point of 20 and with optimal performance. Similarly, YELCYC was approximately 3 when the FR was 120 and the subject was switching at the optimal FR 60. When the FR was 60, S1 switched when the PR was 40 (optimal) as well as when the PR was 60 (inoptimal). In both cases, the YELCYC values were roughly comparable, with values of 2.2 and 3.0 when switching occurred at 60 and 40, respectively; this measure was not very sensitive to optimal versus inoptimal performance. Overall, YELCYC was sensitive to the lowest FR value rather than the higher values. There is no clear evidence that WDCNT changed systematically as a function of either FR value or optimal/inoptimal switching; however, REDCNT did change as a function of FR value.

S2 never said anything that could be scored as YELCYC or REDCNT. This may be a reflection of his WDCNT, which was consistently low across conditions. S3 also failed to emit YELCYC responses, but did respond systematically to REDCNT during FR 20 and 60 conditions. For this subject in these two conditions, REDCNT closely tracked the actual parameter. Interestingly, REDCNT did not appreciably change as a function of optimal/inoptimal switching. S2's and S3's actual data are not reported, because there were too few verbal reports to be meaningful.

#### DISCUSSION

Although each subject received a different sequence of exposures to various FR values, all subjects were given the same pretraining and initial exposure to FR 60 (and they all were returned to that as their final condition). Although the first condition was the same for all subjects (Figure 1), overall patterns of responding were different between subjects. Such between-subject variability is not unusual in human performances on conventional schedules of reinforcement; this variability has been attributed to differing prior histories (e.g., Weiner, 1964, 1969) or to interactions between verbal and nonverbal behavior (e.g., Lowe, 1979).

S3 produced the "best" data, in that she typically showed sensitivity to changing contingencies, but even she (in the final FR 60 condition) and S2 (in all conditions) showed

"transient stability." These subjects' switch points would stabilize, and then suddenly the point at which they switched would change and restabilize at a new value. This phenomenon underscores the importance of extended exposure to experimental conditions when conducting experiments with human subjects, because shorter term exposures would have missed this interesting characteristic. To have reported an earlier switch point as "stable" would have led to inappropriate comparisons.

Skinner's (1969) and Zettle and Hayes' (1982) analyses of verbal behavior predict that subjects would count responses and that switching would become rule governed. Hines and Wanchisen (1989) have reviewed the issues concerning whether such counting should be viewed as a distinct class of behavior or whether it is best considered as simply part of the operant class controlled by the schedule. In either case, this counting might be correlated with subjects' switching at the equality point in each FR condition, especially if counting is a well-engrained behavior in their extralaboratory history of reinforcement. Note that switching at equality departs from the predictions of both the optimality and sums-of-reciprocals theories, but might appear to be the obvious "solution" to subjects whose choice behavior is presumed to be rule governed. S1 did report counting schedule requirements as early as his first exposure to FR 60, and persisted throughout the experiment in stating that equality switching was the solution to the experimental task. His performance may be suggestive of a rule-governed interpretation, but it must be noted that his actual switching did not always agree with his verbalization. Also, the other subjects made no reference whatsoever to counting in any systematic fashion. Of course, this does not mean that they did not count, just that they did not report doing so.

It is interesting to note that S3 reported during the exit interview that once she received a certain amount of money in a given hour, she would sometimes vary her pattern of choices "on purpose" to see if earnings could be increased. In addition, she reported that she would return to former rules when new patterns did not produce superior outcomes. Verbal behavior may account for some of the variability in her data, but it must be noted that occasional variability in responding was reinforced by the experimental procedure be-

cause the FR value was occasionally changed; or, her verbal behavior may simply have been a correlate or a component of her nonverbal behavior. Special manipulations would be required for discerning which of these three possibilities is the case (Hineline & Wanchisen, 1989). Additional relevant data may be obtained by arranging for simple counting and equating of the fixed and progressive ratios to be an unequivocal "best choice"; this was our strategy in Experiment 2.

## EXPERIMENT 2

In this experiment, completion of the FR did not reset the PR to its initial value. This experiment replicated the sequencing in the study of Hodos and Trumbule (1967), in that this no-reset condition followed reset; however, it is similar to the procedures of Hineline and Sodetz (1987) and Wanchisen et al. (1988) in that the progressive schedule began with an initial link requiring one response, whereas Hodos and Trumbule (1967) used a requirement of 20.

## METHOD

### *Subjects and Apparatus*

The subjects from Experiment 1 served as subjects in this experiment, and the intelligence panel described in Experiment 1 served as apparatus.

### *Procedure*

This experiment was similar to Experiment 1 in all respects except that selection of the FR did not reset the PR to its initial value of 0. Instead, throughout a session, the PR continued to increment by 20 responses each time it was selected; the PR requirement returned to 0 only at the start of new sessions. The FR values (in sequence) were 60, 20, 120, and 60. At the conclusion of the experiment, prior to debriefing, subjects were given a pad of paper and were asked to write answers to the questions listed in Appendix A. When they were finished, the debriefing was conducted by the first two authors.

## RESULTS

Median switch points from all sessions for every subject are presented in Figure 2. Two optimal lines are plotted—the equality point and the next higher value—because the re-

sponse cost in responses per reinforcer is the same for both switch points. It is clear from this that median switch points usually varied session by session. The stability criterion was rarely met, resulting in maximum exposures (24 sessions) to each condition. With the exception of S3 on FR 20, where switching consistently occurred in advance of the equality point, and S1 on FR 120, where the median switch point consistently fell beyond the equality point, the daily sessions seemed to converge fairly systematically upon that point.

Both within-session variability and session-to-session variability in switching points were most pronounced in the data for S1, especially in his final two conditions, FR 120 and 60. S2 shows little, if any, variability, and that typically occurred at the start of a new condition. S3 showed her greatest variability in the FR 120 condition; it continued in the initial sessions of her final FR 60 condition.

Table 4 includes the condition median and final three-session block median for all 3 subjects. Considering the condition medians first, we see an increasing value in the subjects' switch point as the FR increases. (Note that S3, in FR 20 and the final FR 60, switched at PR 0. We placed a switch point of 20 in parentheses to indicate that this subject actually *did* select one PR, which means she switched at 20, but because she did this on the final trial of the 40-trial block, our analysis shows the switching to be at 0.) The final block of exposures to FR 60 showed greater deviations from the optimality points than in the subjects' initial exposures to that condition, in which all subjects had switched optimally. In each of the extreme values (20 and 120), 2 subjects switched close to the optimality points in their final blocks of exposure to those conditions.

The data for the final block also showed an increasing switch point value as the FR increased. These data provide further evidence for the variability seen in the two FR 60 exposures. By the final block, 2 subjects were switching optimally in the first FR 60 exposure, but this was true of only 1 subject (S1) in the final FR 60 condition.

## DISCUSSION

It is clear from Figures 1 and 2 that there was considerable fluctuation in the session-to-session median switch point, but that switching eventually converged upon a particular value, usually within one PR increment of the switch

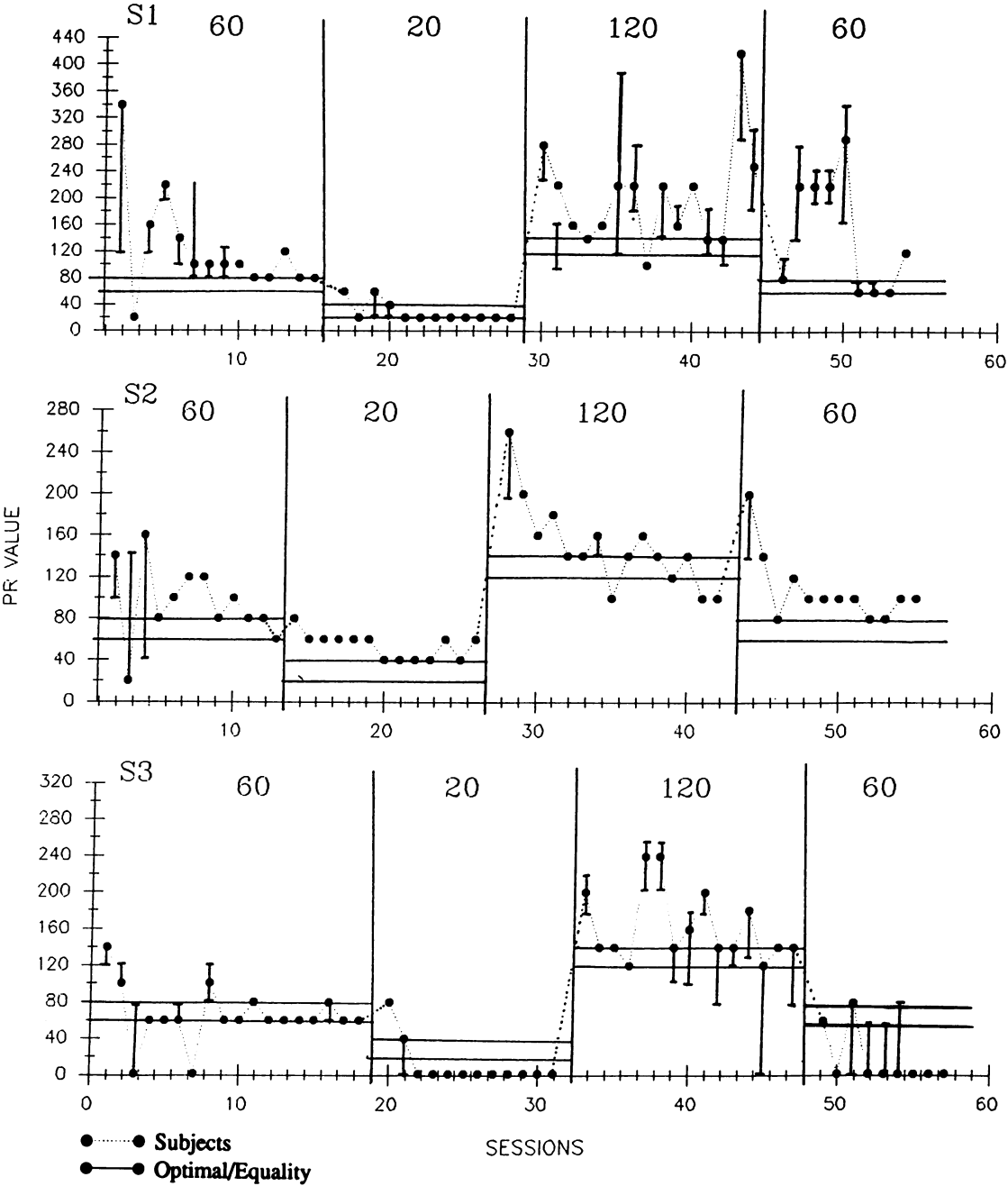


Fig. 2. Session-by-session median switch points for the no-reset procedure, in the order of FR presentation. The solid horizontal lines indicate optimal switch points for the FR value. The solid vertical lines indicate the F spread, a measure of variability about the median.

points that minimized responses per reinforcer. It is even more apparent in the results of Experiment 2 that switching was sensitive to parametric changes in the FR value. The greater fluctuations in switch point under the present no-reset procedure, relative to those

under the reset procedure, are partially explainable in terms of procedural constraints. In the reset condition, selecting the FR reset the PR to 0. The subjects tended to switch earlier under this condition than under no reset. This effectively resulted in a greater num-

Table 4

The condition medians and final-block medians for each subject during the no-reset condition. Optimal switch points at a given FR are provided on the right for ease of comparison. Note that where S3 switched at PR 0, we also parenthetically indicated a switch point of 20. This subject did select one PR (which would normally result in a switch point of 20), but not until the final trial of each session.

FR value	Condition medians			Final block			Optimal switch
	S1	S2	S3	S1	S2	S3	
20	20	60	0 (20)	20	60	0 (20)	20/40
60 (1)	80	80	60	120	80	60	60/80
60 (final)	100	100	0 (20)	60	100	0 (20)	60/80
120	160	140	140	140	100	140	120/140

ber of switch point determinations per session, in turn reducing session-to-session switch point variability.

A related issue is that the no-reset procedure provides that a given PR value may be selected only once per session. This aspect of the no-reset procedure contributed to interesting effects in S3's data. In the FR 20 condition, she chose the PR once and the FR 39 times (which is optimal in terms of cost). She differed from S1, however, in *when* she selected the PR. S1 began sessions by selecting the PR 0 and then selecting the FR 20 for the remaining 39 trials of the session. S3, in contrast, began sessions with 39 FR 20 selections and collected the PR 0 at the end of the session. Her median switch point is reported as 0 because, on median, she chose the FR when the PR was 0; both subjects, however, selected the FR the same number of times, and both incurred the same number of responses per reinforcer. Although both performances are identical on a molar level, the median measure treats them as different. (Note, however, that order of choice is crucial in the reset procedure of Experiment 1; selecting the PR only at the end of sessions would be highly inefficient from the perspective of virtually all choice theories.)

S3 stated in her exit interview that she waited to select the PR until the end of each session because this caused the 2-min period between sessions to shorten. We reviewed the software controlling the experiment but failed to detect any programming errors that could have validated her hypothesis. Clearly, it is doubtful that S3 would have chosen in this fashion if the design had been such that she could not reliably discriminate when sessions were about to end. Obtaining this pattern of results with a human subject is especially interesting, because it is as optimal from a molar perspective

as selecting the PR at the beginning of the session, yet nonhuman subjects have never been observed to "save" the PR 0 until the end of the session. It should be noted, however, that blue jays have been shown to be sensitive to impending session termination in a foraging paradigm (Kamil & Yoerg, 1988), and session shortening was shown to be a sufficient consequence to affect rats' choices of alternative levers for avoidance responding (Mellitz, Hineline, Whitehouse, & Laurence, 1983).

There are a variety of interpretations that can be offered for S3's unusual performance of switching at PR 0. At one level, one could speculate that selecting the PR might occur at any point during the session, provided that the subject can discriminate the fixed length of sessions. This does not, however, explain why this subject specifically waited until the end of sessions to collect the PR 0. Some might argue that waiting may have been rule governed, as suggested by S3's verbal reports. Alternatively, without appealing to explanations unique to humans, waiting may have reflected the joint contribution of both conditioned reinforcement and sensitivity to the fixed session length. As noted in the procedure of Experiment 1, the yellow lamp blinked whenever the PR was 0 and did not blink when the PR was greater than 0. As a stimulus correlated with a differentially high rate of reinforcement, the flashing yellow lamp may have been established as a conditioned reinforcer. The subject may have delayed collecting the PR 0 reinforcer because continued exposure to the flashing stimulus (correlated with high reinforcement density) was relatively more reinforcing than exposure to the solid yellow and red stimuli. Further, this effect might be anticipated only in situations in which session duration is highly discriminable, as in the present exper-

iments. If session length is not discriminable, then delaying PR selection until the end of the session risks not collecting the PR 0 before session termination. This phenomenon may have been seen only in humans because of differences in the nature of the reinforcer used in this experiment versus experiments with nonhuman subjects. In the prior experiments (e.g., Hineline & Sodetz, 1987; Hodos & Trumbule, 1967; Mazur & Vaughan, 1987; Wanchisen *et al.*, 1988), all subjects were food- or water-deprived, and maximizing local rate of reinforcement at the beginning of experimental sessions might reasonably facilitate continued and efficient performance throughout the remainder of the session. In contrast, the present experiments utilized a generalized reinforcer (points) that could not be exchanged for money (another generalized reinforcer) until the end of the experimental hour. The present data do not permit differentiation among the various alternatives, but further experimentation might differentiate among these possibilities.

Given the limitations of the no-reset condition and the sporadic nature with which subjects responded, a quantitative analysis was not warranted.

## GENERAL DISCUSSION

This discussion will address the following: (a) a comparison of results from Experiments 1 and 2, with comparisons also made with studies of nonhumans on these procedures, (b) the role of verbal reports, and (c) the importance of studying humans for extended periods of time.

### *Comparisons across Species*

Comparing the session-by-session performances in both experiments, Figures 1 and 2 reveal that although, at times, stability was transient in the reset procedure, overall there was greater stability there than in the no-reset procedure. Aside from the unusual behavior of S3 (in the FR 20 and final FR 60 conditions), the median switch point in the no-reset condition varied with nearly every session. This same pattern was also seen with pigeons (Wanchisen *et al.*, 1988).

In terms of the measure of within-session dispersion, greater variability was seen in S1's switching under no reset (Experiment 2, see Figure 2) than in reset (Experiment 1, see

Figure 1), whereas very little variability was seen in the responding of S2 in no reset compared to reset. S3 showed the greatest variability in the final two conditions of no reset (FR 120 and 60). Overall, it seems that no reset produced greater variability, especially taking into account that any novelty effects of the experimental setting would have greatly habituated by Experiment 2. (This may have at least partly accounted for the variability seen in the first condition of the reset procedure.)

The difficulties of extending an experimental paradigm developed with nonhuman subjects to humans are illustrated by an interesting relationship obtained between subjects' response rates and earnings. It was not always the case that those subjects who switched closest to the optimal switch points earned the most money per hour. S1, for example, responded extremely quickly and earned a great deal of money per experimental hour, whereas S3 earned less even though she emitted the fewest responses per reinforcer. In terms of rate of reinforcement, it sometimes can be better to make a few errors and maintain high rates of responding than to make careful choices while responding more slowly. Of course, S1 would have earned even more money (compared to his actual earnings) by switching more optimally, and S3 would have made more if her speed were greater. Therefore, total earnings were determined by at least two factors: rate of responding and the points within the PR sequence at which the subject switched to responding on the FR from the PR. Perhaps a procedure that imposes constraints upon response rate would more adequately differentiate these sources of control.

In addition, it is difficult to compare human with nonhuman behavior, given inherent differences in procedures (e.g., using secondary reinforcers with humans and primary reinforcers with nonhumans; for a review of this subject, refer to Perone *et al.*, 1988). Our experiments entailed another procedural difference in that the humans were allowed to participate in a number of sessions per day, whereas nonhumans typically received one session per day. Although the data from the present experiments are presented as cross-species replications, these procedural differences argue for restraint in comparing the present data to those obtained with nonhumans. As stated in our introduction, we had planned on comparing these human data with nonhuman data

in terms of the molar/molecular controversy, but have concluded that to do so might be misleading because of these procedural differences.

### *Verbal Reports*

Care should be taken not to imply that covert verbal behavior has special causal functions. Also, lacking adequately controlled measures, it should not be inferred that self-reports can function as discriminative stimuli upon which schedule performances are occasioned. We found no reliable evidence for such effects. It is likely that the schedule and the resulting performances occasioned certain types of verbal behavior, just as was true with nonverbal behavior. It may also be that our procedures for explicit assessment of verbal guesses prompted describing the contingencies and that omitting guess sheets would have produced very different results. Comparison of results with and without the prompting of verbal descriptions may reveal the role of subject-generated descriptions (Hayes, 1986). Alternatively, guess sheets may have had no effect on schedule performances. It is equally likely that verbal reports do not necessarily reflect the fundamental determinants of human schedule performance but rather reflect the fact that people sometimes describe their own behavior as the result of the reinforcing practices of the larger verbal community (Lloyd, 1980; Nisbett & Wilson, 1977). Verbal reports should be studied (as is the current trend in behavioral research) but must be interpreted with caution (Shimoff, 1986). There was little evident orderliness to the verbal data collected in the present experiments (cf. Bernstein & Michael, 1990; Critchfield & Perone, 1990). Indeed, it was apparent from exit interviews that the subjects were largely unable to describe even the most rudimentary aspects of the procedures. The subjects did not express well-formed descriptions and rules (either accurate or inaccurate) pertinent to the experiment; instead, they expressed only vague impressions.

A difficult choice procedure, especially that of Experiment 1, may be a reasonable way to study some aspects of verbal behavior. The reset procedure may be an especially useful paradigm due to its nonobvious optimal strategy. That is, when this procedure has been described in full to other experimental psychologists, they typically have not reported the optimal strategy, even after considering the

effects of various patterns (without the aid of calculating devices or pencil and paper). It seems reasonable to say that the mathematical characteristics of the reset procedure are counterintuitive and thus particularly appropriate for studying human problem solving and verbal behavior. But a major challenge lies in deciding how best to collect verbal reports (e.g., providing open-ended statements or multiple-choice/forced-choice answers, providing reinforcement for the verbal reports or not). As stated earlier, we were concerned with not prompting particular verbal statements (i.e., "leading"), so we provided minimal instructions and submitted open-ended guess sheets. But the flip side of that procedural decision is to accept vague reports, intermittent ones, or worse, none at all.

### *Methodology of Human Research*

Finally, Figures 1 and 2, in presenting session-by-session data, underscore what some have said about the importance of providing humans with extended exposure to schedule contingencies (Sidman, 1960), and that in many recent experiments, exposure is usually too short (Bernstein, 1988). Indeed, books on methodology suggest that humans be exposed to experimental contingencies as long as non-human subjects (Barlow & Hersen, 1984; Johnston & Pennypacker, 1980). Unfortunately, research done on humans is commonly too brief. This is true in all areas of psychological research, but has also become prevalent in behavior analysis. In our present experiments, had we changed conditions when switching first appeared "stable," we would not have seen the sometimes dramatic shifts that followed supposedly stable behavior.

Conducting cross-species replications of operant paradigms may provide insight into behavioral similarities and differences found in humans and nonhumans. For this to be effective, conditions must be kept as similar as possible (Perone et al., 1988). This continues to be a serious difficulty in the study of operant schedules of reinforcement, particularly when humans with rich histories of reinforcement serve as subjects (Wanchisen, 1990; Wanchisen et al., 1989).

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## APPENDIX A

1. Overall, what strategies did you use to earn points? Why did you use these strategies? Please be specific.

2. (a) What do you think we wanted you

to do? (b) How well do you think you performed? (c) Is there anything you should have done differently?

3. What do you think was the point of the

study in the very beginning as opposed to now? Did your views change as the experiment progressed? Please be specific.

4. What were the best and worst aspects of the study?

5. Did you think about this experiment when you left the room? If yes, what did you think about and how did your thoughts affect your performance in the experiment?

6. Did you discuss the experiment with anyone? If yes, what did you talk about and how did this help or hinder your efforts?

7. How would you describe this experiment to other people (i.e., friends, family, etc.).

8. What, if anything, did you think about while you pushed the panels? What, if anything, did you think about when you finished the guess sheet and were waiting for the panel to light?

9. You probably noticed that the number of pushes on the red panel changed from time to time. On what basis did we change the red panel?

10. Any additional suggestions or comments you would like to make will be welcome here, as we will be conducting this experiment in the future and your comments can help improve the study.

## APPENDIX B DICTIONARY OF CODING TERMS

### CONTINUOUS CATEGORIES

1. WDCNT. Tally the total number of words, including articles (a, an, the). Also include "verbal" numbers (but not the digits comprising the numbers) and abbreviations, such as &. Do not count diagrams, punctuation marks, etc.

2. YELCYC. When the subject makes statements of the form, "yellow yellow yellow" or "Y Y Y," then press red (or R) for the rest of the session, record "3." Or if the subject says "I do the pattern of Y Y then R and repeat that pattern until the end of the session," record "2." Any reference to "flash," "flashing," or "flashing yellow" counts as one yellow count.

3. REDCNT. If the subject states that the red button requires a specific number of presses or that he or she presses the red button a specific number of times in order to make the counter increment, then record the number of presses the subject states.

### DISCRETE CATEGORIES

1. IFAST. Simple descriptions of pressing "quick," "fast," "rapid," "as fast as possible," "speed." This must be in reference to the subject's own behavior, not what the machine (computer, experimenters, etc.) requires or in reference to the adequacy of responding in that fashion. Subject may omit reference to him or herself.

Example: "I press rapidly" or "hit rapidly" or even "rapidly," NOT "I press rapidly to get points."

2. YFAST. Descriptions of pressing "quick," "fast," "rapid," "as fast as possible"

BECAUSE: "I'm supposed to," "I get money (points) for this," "the machine beeps when I do this." In other words, the subject directly explains WHY he or she is pressing fast or that pressing fast is what he or she is supposed to do or pressing fast is the best thing to do. Subject may omit reference to self.

Example: "I press rapidly to get points" or "quick hits earn money," NOT "I press rapidly."

3. ISLOW. Simple descriptions of pressing "slowly." This must be in reference to the subject's own behavior, not what the machine (computer, experimenters, etc.) requires or in reference to the adequacy of responding in that fashion.

Example: "I press slowly," NOT "I press slowly to have the counter add."

4. YSLOW. Descriptions of pressing "slow" BECAUSE: "I'm supposed to," "I get money for this," "the machine beeps when I do this." In other words, the subject directly explains WHY he or she is pressing slowly or that pressing slowly is what he or she is supposed to do or pressing fast is the best thing to do. Reference to self is optional.

Example: "I press slowly to get points" or "press slow," NOT "I press slowly" or "tap slowly."

5. BODY. Subject refers to being tired or sore of hand or other *physical* complaints.

6. AGGRESS. Subject complains of being "pissed," "cheated," "ripped-off," "annoyed," etc. or states "why are you doing this to me" or something like that.

7. POSITVE. Subject clearly indicates a

positive "mood" via statements such as "this is great!" "I'm happy to see it's changed today."

8. BLANK. The question is left blank.

9. NOCLUE. "I don't know," "I'm not sure," "I have no idea," "?"

10. EXCLAM. At least one exclamation point is present.

11. IBEEPCTR. The subject says that he or she is making the counter add, increment, beep, count, get points, money, cents, etc. or any reference to beeping or making the lights go out. The subject may omit references to himself or herself. The subject must not refer to being *required* to make the counter increment or beep and must not state that the object is to make the counter beep.

Example: "I make the counter beep" or "beep beep," NOT "The object is to make the counter beep."

12. YBEEPCTR. The subject says that the goal or requirement of the task is making the counter add, increment, beep, count, get points, earn cents, etc. or any reference to beeping or making the lights go out. The subject *must* refer to being *required* to make the counter increment or beep. Subjects may omit reference to self.

Example: "I must make the counter beep," NOT "I make the counter beep."

13. FLASHY. The subject states that the flashing yellow lamp requires only one press (or fewer or faster points than something else) to make the counter increment or beep.

14. LSSWKSES. Stating that fewer presses or less work is required during the present session or day *than during previous sessions*. They will normally refer to "yesterday" or earlier in the week or on a particular day or other phrases that indicate they are speaking of a prior session.

15. MRWKSES. Stating that more presses or more work is required during the present session *than during previous sessions*. They will normally refer to "yesterday" or earlier in the week or on another day of the week or other phrases that indicate they are speaking of a prior session.

16. LSSWK. Subject states that doing a particular thing requires less work or is easier than doing something else *within* that session.

17. MREWK. Subject states that doing a particular thing requires more work or is not easier than doing something else *within* that session.

18. RED2Y. Stating that completing pressing the red button causes the yellow to blink or makes the yellow easier. Alternately, the subject could say that in order to get a flashing yellow, one must complete the red first.

19. RED2PAT. Stating that completing pressing the red button causes a pattern of events to restart or reset. Terms such as ordering or sequencing used in this context may be substituted for pattern or strategy.

20. PATTRN. Stating that there is a pattern or strategy or cycle or method that he or she is following or that could or should be followed. Terms such as ordering or sequencing used in this context may be substituted for pattern or strategy.

21. LOOKPAT. Stating that he or she is trying to discern an appropriate strategy or pattern. Additionally, accept statements that he or she believes that there is a pattern or best way to perform the task, even if the subject states that he or she does not know the ideal pattern. Terms such as ordering or sequencing used in this context may be substituted for pattern or strategy.

22. FOUNDPAT. Stating that he or she has discovered an appropriate pattern or has locked into an appropriate pattern.

23. NODIFF. Statements of the form "It doesn't matter what I do," "It doesn't matter," "There is no pattern," "There is no best way to do this task." Also accept reference to random key pressing or random switching.

24. IPRESS. Statements of the form "I press (push, hit, tap, pound) the button 20 times" or "press/push 20 times." There must be a reference to *number* of presses, but references to color (red or yellow) are optional. It is not necessary for the subject to refer to himself or herself.

25. YPRESS. Statements of the form "I must press (push, hit, tap, pound) the button 20 times." There must be a reference to *number* of presses and explicit indication that pressing a given number of times is required or desirable, but references to color (red or yellow) are optional.

26. MATH. If the subject indicates he or she has added presses and/or divided by the number of reinforcers (or money) earned. Do not mark if subject simply reports how much money was earned.

27. MONEY. Statements of total or partial earnings like "I earn 2 cents" or "I have earned

over two dollars." Vague statements like "I earn money" should not be coded.

28. **VARIED.** Statements indicating that the amount of presses that are required *within a particular color* varies, e.g., "the yellow light changes the number of presses required each time," or "red indicates change or inconsistency or chance."

29. **FIXED.** Statements indicating that the same number of presses is required *within a particular color*, e.g., "no matter what, it always takes 60 presses" (notice that here you would also get the red count-REDCNT) or "the red is consistent or means no change in presses."

30. **YVARIED.** Yellow (or Y) gets harder or increases or varies.

31. **RFIXED.** Red (or R) is constant, same or fixed.

32. **ANTICIP.** References to anticipation or being ready.

33. **ACCURACY.** Reference to being careful to accurately choose or accuracy as important in the task.

34. **TIME.** References to being aware of how much time is left in the session. "I will do this because there isn't time to do that" or "there is a lot of time to play with this" or "there is not time to finish getting points."

## CODING INSTRUCTIONS

### CONTINUOUS CATEGORIES

1. Count the number of words in the sample AND write the number of words next to WDCNT.

2. If indicated, as described in the coding

dictionary, provide numbers for the YELCYC and REDCNT categories. If the subject did not provide enough information for you to score these categories, leave the categories blank—do not enter "0."

### DISCRETE CATEGORIES

3. Be sure at all times to code exactly what is there and not inferences you might make based on what is there. For example, if a subject provides a table detailing a sequence of yellow and red selections, score only the number of yellow (YELCYC) but do not code that a pattern is present (PATTRN) nor that pressing red causes flashing yellow (RED2Y) nor that pressing red causes a pattern to restart (RED2PAT). Record the number you identify on the space provided on the guess sheet. Mark as many categories as appropriate.

4. If you can't decide between two *opposing* choices on the Dictionary of Coding Terms *because* both are presented on the answer sheet (i.e., subject makes two guesses and/or says "it's either this or this") then fill in the two separate grids on the sheet. Also, if you select more than 10 discrete categories, use the second grid provided without filling in the continuous categories a second time.

5. If there is something in the verbal report that is not covered by the codes provided, put those reports aside and discuss with the arbiter.

NOTE that there may be some overlap between these three: (1) IBEEPCTR/YBEEPCTR, (2) IPRESS/YPRESS, and (3) IFAST/YFAST. It is OK to have one from each category, and very often (1) and (2) are linked.